Applying Gamification Technology to Enhance Student Engagement in High School Mathematics

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***Abstract*—This research paper examines the effects of a gamified educational application on student engagement and academic performance, focusing particularly on gender differences in response to gamification. Employing a blend of quantitative methods—including independent samples t-test, Analysis of Variance (ANOVA), Analysis of Covariance (ANCOVA), and Cohen's d for effect size calculation—and qualitative feedback from focus groups, the study conducts a detailed analysis of how gamification impacts students in a secondary school environment over a 10-week period. The findings reveal that gamification not only significantly boosts student engagement but also leads to improvements in academic performance. Notably, female students displayed higher levels of engagement than male students, suggesting gender-specific receptivity to gamified learning. These results underscore the potential of gamified approaches to enhance educational engagement and effectiveness. Additionally, the positive outcomes pave the way for extended studies over semester and full academic year durations, incorporating gamified learning into regular curricula. The study promotes the development of customized gamification strategies to cater to varied learning preferences and calls for further investigation to optimize the use of gamification in educational settings. This contribution enriches the educational technology literature by articulating the subtle impacts of gamification and its implications for educational practices and policies.**

***Keywords*—gamification, student engagement, academic performance, educational technology, quantitative analysis, qualitative insights**

I. Introduction

As educational paradigms evolve, the adoption of gamification stands out as a dynamic strategy to invigorate student engagement and motivation, especially in subjects that students traditionally find difficult, like mathematics. The principle behind gamification is the infusion of game-design elements into non-game contexts, aimed at bolstering engagement, organizational productivity, and educational outcomes [1]. This innovative approach has become increasingly popular across educational settings as a means to address the steady decline in student interest and engagement, notably during the high school years [2].

The increasing disengagement in mathematics is a significant concern, as it is a foundational subject that influences students' academic and professional futures [3]. Research indicates that a substantial proportion of high school students feel disconnected from the content and methods traditionally employed in mathematics education, which can lead to lower academic achievement and reduced interest in Science, Technology, Engineering, And Mathematics (STEM) related careers [4]. Therefore, it is imperative to explore innovative strategies that can rejuvenate interest and improve understanding in mathematics.

Gamification in education leverages elements such as point scoring, competition, and rules of play, which have been shown to enhance student participation and motivation [5]. By integrating these elements, educators can transform the learning environment into a more dynamic and interactive space that encourages students to engage deeply with mathematical concepts [6]. Moreover, gamification strategies can be particularly effective in personalized learning, providing pathways tailored to the diverse learning speeds and styles of students [7].

Several studies have demonstrated the positive effects of gamification on learning outcomes. For instance, incorporating game mechanics in educational settings has been linked to increased motivation, enhanced engagement, and improved academic performance [8]. Specifically in mathematics, gamification has been found to reduce anxiety and increase enjoyment, which are critical factors in improving students' attitudes towards the subject [9]. Furthermore, gamification provides immediate feedback, which is crucial for learning mathematics as it helps students quickly understand their mistakes and correct them [10].

Despite these benefits, the implementation of gamification is not without challenges. The primary concern is the quality of the gamification design, which must align well with educational objectives to be effective [11]. Poorly designed gamification can lead to gamification for its own sake, which might distract from the learning objectives rather than support them [12]. Additionally, there is a need for comprehensive training for educators to effectively implement and sustain gamification strategies in their teaching practices [13].

Despite the increasing application of gamification in educational settings, there remains a significant gap in understanding its specific impacts on mathematics education at the high school level [14]. While gamification has been extensively studied in general educational contexts, less attention has been paid to its effectiveness specifically in enhancing mathematical skills and knowledge. This gap is crucial given the unique challenges and requirements of mathematics education, which often demands not only engagement and motivation but also deep cognitive processing and problem-solving skills. Current literature often highlights the general benefits of gamification without delving into how these benefits translate into actual learning gains in mathematics, particularly in a classroom setting [15–17]. This study, therefore, seeks to fill this research gap by providing a detailed examination of how gamification can specifically affect mathematical engagement and achievement among high school students. Through a rigorous analysis of gamified learning outcomes compared to traditional methods, this research aims to contribute targeted insights into effective educational practices and design principles that can make gamification a more potent tool for enhancing mathematics education.

This study aims to address the gap in the literature regarding the application of gamification in high school mathematics by exploring its effects on student engagement and academic achievement. By implementing a gamified curriculum in mathematics classes and measuring various metrics of student engagement and performance, this research will provide empirical evidence on the effectiveness of gamification as an educational tool. Additionally, it will offer insights into how gamification can be designed and implemented effectively to maximize educational outcomes in mathematics education.

As educators and researchers continue to seek effective methods to engage students in mathematics, gamification presents a promising approach. By understanding the mechanisms through which gamification can affect learning and by addressing the challenges associated with its implementation, this study contributes to the broader discourse on educational innovation and its potential to transform learning experiences in high school mathematics.

II. Literature Review

This section systematically examines the extensive body of research surrounding the application of gamification in educational settings, particularly focusing on its theoretical underpinnings, implementation, and impact on student engagement and learning outcomes. This review not only elucidates the diverse perspectives and findings related to gamification but also identifies the gaps that this study aims to address. The comprehensive exploration of existing literature is segmented into distinct areas, beginning with the foundational theories that support gamification.

A. Theoretical Foundations of Gamification

Theoretical frameworks such as the Self-Determination Theory (SDT) and the Flow Theory provide insight into how gamification can enhance learning experiences. According to SDT, gamification can satisfy basic psychological needs—competence, autonomy, and relatedness—which are essential for intrinsic motivation [14–15]. Flow Theory further explains that gamification can create a state of flow in students, characterized by a profound focus on tasks that challenges their skills just enough to keep them engaged but not overwhelmed [16].

Another critical theoretical foundation is the Flow Theory, introduced by Wojtasiński *et al*. [17], which describes a state of heightened focus and immersion in activities that perfectly balance the challenge with the individual's skill level. Gamification strategies, through their incremental challenges and instant feedback, can foster this flow state in educational activities, making learning both effective and enjoyable.

Cognitive Evaluation Theory (CET), a sub-theory of SDT, also offers insight into how external rewards offered by gamification, such as badges and points, can influence intrinsic motivation. CET suggests that if such rewards are perceived as controlling or coercive, they could diminish intrinsic motivation; however, if they are aligned with the learners' values and sense of autonomy, they can enhance motivation [18].

Moreover, the Goal Setting Theory asserts that gamification can help in setting specific, challenging, and attainable goals, providing direction and structure to the learning process, which in turn can improve student performance and persistence [19]. Gamified systems often allow for clear goal-setting and real-time feedback, which are crucial for effective goal pursuit.

Additionally, the concept of situated cognition, which argues that knowledge is constructed within and linked to the activity, context, and culture in which it is used, aligns well with gamification. Gamified learning environments, by simulating real-world contexts, can provide situative engagement that deepens learning and retention [20].

Lastly, the theory of extrinsic and intrinsic motivation plays a significant role in gamification. Gamification elements like leaderboards and point systems cater to extrinsic motivation, while the underlying challenges and storytelling elements foster intrinsic motivation, which is critical for long-term engagement and success in learning [21].

Together, these theories provide a robust framework for understanding the mechanisms through which gamification can enhance educational experiences and outcomes. They not only support the use of gamification in learning environments but also guide the design of gamification to maximize educational benefits while minimizing potential drawbacks.

B. Gamification in Educational Contexts

Gamification has been increasingly recognized as a potent tool in educational contexts, leveraging the motivational potential of game elements to transform traditional learning environments into engaging and interactive spaces. Schools and universities worldwide have begun integrating gamified elements such as points, badges, and leaderboards to mimic the engaging nature of games, thereby motivating students to participate more actively in their learning processes [22]. This strategy has been particularly effective in courses that typically see low engagement and motivation, such as mathematics and science, where gamification introduces a sense of challenge and achievement through incremental rewards and feedback systems [23].

Educators employ gamification not only to increase student engagement but also to facilitate deeper learning and collaboration among students. For instance, group challenges and leaderboards can foster a healthy competitive environment, encouraging teamwork and peer learning, which are essential aspects of the educational process [24]. Moreover, the adaptive nature of gamified learning allows it to cater to various learning styles and paces, providing personalized education paths that are both inclusive and effective [25]. Through these applications, gamification is proving to be a transformative educational approach, adapting to the needs and motivations of 21st-century learners.

C. Impact on Student Engagement and Learning Outcomes

The impact of gamification on student engagement and learning outcomes has been extensively documented, revealing a predominantly positive influence across various educational settings. Studies consistently show that gamification enhances student engagement by making learning experiences more interactive and rewarding, which in turn can lead to higher academic performance and retention rates [26]. This is particularly evident in environments where students are initially disengaged or where the subject matter is perceived as challenging or uninteresting [27].

Furthermore, the introduction of game mechanics such as immediate feedback, achievement badges, and progress tracking aligns closely with motivational theories in education, which suggest that timely and clear feedback enhances learning effectiveness by allowing students to recognize their learning progress and areas needing improvement [28]. The dynamic setup of gamified learning environments also supports diverse learning modalities, catering to visual, auditory, and kinesthetic learners by integrating various multimedia and interactive elements [29].

Moreover, empirical research has validated that gamification can bridge the gap between knowledge acquisition and application. This is achieved by situating learning in a context that simulates real-life scenarios, making the learning process not only theoretical but also practically applicable [30]. Thus, gamification not only boosts engagement but also enhances the holistic learning outcomes essential for students' academic and professional growth.

D. Gamification and Educational Outcomes: Insights from Previous Research

The integration of gamification into educational settings has been extensively explored, with varying impacts on student engagement and academic performance documented across different studies. Research consistently highlights that gamification can enhance student engagement by introducing game-like elements—such as points, levels, and rewards—into the learning environment. For example, Adams and Preez [31] and Rajput *et al*. [32] both report increases in intrinsic motivation and enjoyment among students exposed to gamified learning activities, suggesting that these methods can make educational tasks more appealing and engaging.

Conversely, the effects of gamification on academic performance have been less conclusive. While some scholars argue that gamification can lead to improved learning outcomes by maintaining higher levels of student interest and participation [33], others, like Kaya and Ercag [34], caution that the benefits may depend heavily on the design of the gamification system and its alignment with educational goals. This variability indicates that while gamification has potential, its effectiveness is influenced by factors such as the educational content, context, and implementation strategy.

Additionally, the literature reveals potential gender differences in responses to gamified learning. Studies have suggested that male and female students may react differently to gamified elements due to differing gaming experiences and preferences [35–37]. This aspect of gamification research underlines the importance of designing flexible gamification strategies that can be adapted to diverse student populations and learning styles.

Collectively, these studies provide a comprehensive background that informs the current exploration of gamified learning environments. By drawing on these insights, the present research aims to further elucidate how gamification can be optimized to support educational engagement and effectiveness, particularly in the challenging subject of mathematics. This endeavor will contribute to a more nuanced understanding of gamification's role within educational innovation, ensuring that its application maximizes benefits while mitigating potential drawbacks.

E. Challenges and Considerations

While gamification presents numerous advantages for educational enhancement, it also introduces several challenges and considerations that must be addressed for successful implementation. One of the primary concerns is the potential for gamification to emphasize extrinsic rewards over intrinsic learning motivations. The over-reliance on points, badges, and leaderboards might lead to a scenario where students are motivated solely by rewards rather than the joy of learning or the mastery of content, potentially undermining long-term engagement and deep learning [38].

Additionally, the design and integration of gamification require significant effort and expertise. Poorly designed gamified elements can lead to confusion, distraction, or even disengagement if they do not align well with the learning objectives or are too complex to understand [39]. This necessitates educators and curriculum designers to possess or develop a deep understanding of both game design and pedagogical principles, which can be a barrier in terms of resources and training [40].

Moreover, there is the risk of inequity, where gamification might inadvertently favor students who are more competitive or more familiar with gaming conventions. This can widen the achievement gap between different groups of students unless gamification is carefully tailored to be inclusive and supportive for all learners [41].

Therefore, while gamification holds promise, it requires careful planning, thoughtful design, and ongoing assessment to ensure it contributes positively to educational outcomes without unintended negative consequences.

III. Methodology

This study employed a quasi-experimental approach with non-equivalent groups, primarily utilizing quantitative methods supplemented with qualitative elements. The research was conducted with two groups: a control group and an experimental group. The control group engaged in traditional educational methods, which emphasized teacher-led instruction and rote memorization of material. In contrast, the experimental group used specially designed instructional approaches that incorporated a gamified learning environment, following a similar lesson plan structure. Both groups consisted of students from four ninth-grade classes at Secondary General Education School No. 59 in Shymkent, Kazakhstan. Fig. 1 demonstrates flowchart of the study.

A. Sample Selection

The selection of the school was based on convenience sampling, as the facility was well-equipped with accessible computer resources. The sample comprised 120 ninth-grade students (aged 12–15 years) from a secondary general education school located in Shymkent, Kazakhstan. Participants were randomly assigned to either the experimental group or the control group, with each group consisting of 60 students (30 boys and 30 girls). This balanced distribution was designed to ensure comparability and control for gender-related variables in assessing the impact of the gamified learning environment versus traditional teaching methods.

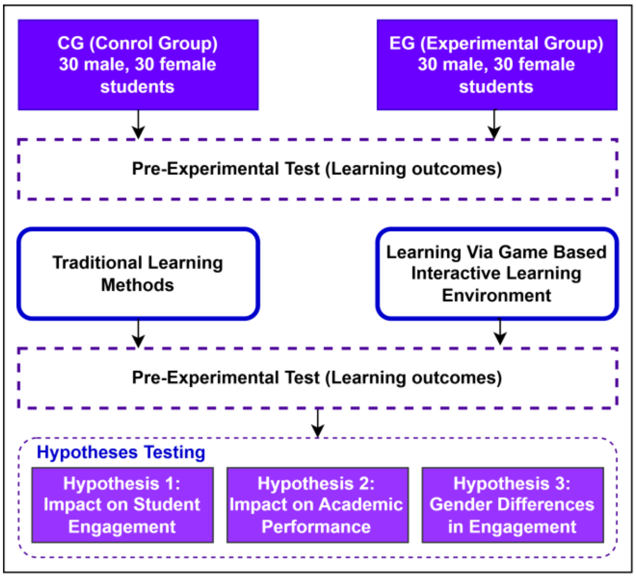

Fig. 1. Design and methodology of the experiment.

B. Requirements and Learning Participants

Prior to the commencement of the study, a preliminary survey was conducted that identified students' difficulties in understanding chemistry, a subject requiring practical application. As part of this research, a Game-Based Learning (GBL) application was developed for studying geometry, specifically focusing on the lesson "Constructing Sections". This lesson addresses techniques for constructing sections and explores their significance in everyday life. It is important to note that the students come from varied socio-economic backgrounds. The developed application is designed for use in an accessible general education school and among homeschooling students who, for various reasons, prefer not to attend traditional school sessions.

C. Evaluation Criteria for Student Outcomes

The initial assessment on the knowledge of cross sections in stereometry provided a baseline understanding of students' proficiency before engaging with the GBL application. Upon completion of the educational module using this application, student performance was evaluated based on the following criteria:

1) Conceptual Understanding: Evaluating the depth of students' understanding of cross-sectional geometry principles.
2) Application Skills: Assessing students' ability to apply theoretical knowledge to solve practical problems involving cross sections in stereometry.
3) Improvement in Spatial Visualization: Measuring the enhancement in students' ability to visualize and interpret three-dimensional shapes and their cross sections.
4) Engagement and Interaction: Quantifying the level of active participation and engagement within the GBL application, particularly in modules dealing with cross sections.
5) Retention of Knowledge: Determining the extent to which students retained information about cross sections over time after using the GBL application.

D. Impact of Gamification on Learning Outcomes

In developing the instructional content aimed at enhancing learning efficacy and increasing student engagement, the following gamification elements were incorporated: feedback mechanisms, points, visual effects, challenges, background music, interactivity, goals, progress tracking, and levels. Moreover, within the interactive learning environment facilitated by this application, students were able to achieve specific educational objectives:

1) Mastery of Key Concepts: Students demonstrated a deep understanding of the core principles related to the subject matter, achieving mastery through incremental challenges tailored to their learning pace.
2) Enhanced Problem-Solving Abilities: Learners effectively applied theoretical knowledge to real-world scenarios, solving complex problems that reinforced their learning and critical thinking skills.
3) Increased Motivational Engagement: The gamified elements such as points and levels increased students' intrinsic motivation, encouraging continuous engagement and participation in the learning process.

E. Designing Game Based Interactive Learning Environment

The study utilized Unity 2D version 4.3 as the primary platform for designing and developing the interactive learning application, ensuring compatibility with modern educational technology and game-based learning principles. The interactive environment was structured around 10 lessons specifically designed to align with the learning objectives of the "Construction of Sections" module, a theme introduced in the fourth quarter of the ninth-grade curriculum. This timeframe was selected to coincide with the structured learning progression, ensuring that students had the necessary foundational knowledge to engage meaningfully with the gamified content during the 10-week study period.

To assess the efficacy of game-based learning, the study employed a quasi-experimental design with two distinct groups: a Control Group (CG) consisting of 30 male and 30 female students engaging with traditional instructional methods, and an Experimental Group (EG) with an identical composition that participated in the game-based learning intervention. Prior to the intervention, both groups completed a pre-test to establish baseline academic performance and engagement levels. The CG followed conventional teaching methodologies, while the EG engaged with the interactive game-based learning platform. After the 10-week instructional period, both groups completed a post-test, allowing for a comparative analysis of the effects of gamification on engagement and academic achievement.

The gamification strategy incorporated several key elements to enhance student engagement, including points, badges, leaderboards, and adaptive challenges. These features were designed to promote motivation, foster competition, and create a personalized learning experience. Student engagement was quantitatively measured using real-time interaction logs, tracking participation frequency, completion rates, and in-game progress metrics. Additionally, a self-reported engagement questionnaire was administered at the end of the intervention to capture students' perceptions of their learning experience.

To complement the quantitative findings, qualitative data collection was conducted through semi-structured interviews and classroom observations. The interviews explored students' experiences, motivation levels, and perceived effectiveness of game-based learning. Observational data were analyzed to assess behavioral engagement, collaboration patterns, and problem-solving approaches. These qualitative insights provided a deeper understanding of how game-based learning influenced student interactions and cognitive engagement beyond numerical performance metrics.

The study systematically tested three hypotheses:

H1: The game-based interactive learning environment positively influences student engagement compared to traditional learning methods.

H2: The interactive learning environment enhances academic performance more effectively than traditional approaches.

H3: There are significant gender-based differences in engagement levels within the game-based learning framework.

Table 1 details the gamification elements incorporated into the aforementioned digital learning activities, which aim to enhance user engagement and the educational process, as reviewed in the literature section.

Table 1. Game elements embedded in interactive gamified learning environment application

Game Elements	Application
Levels	Three levels (easy, medium, hard).
Progression	A rack in the lower right corner of the user's screen for placing items.
Points	Increase the number of points for the correct answer.
Feedback/Help	1) Information pops up. 2) Correct or incorrect responses.
Interactivity	1) Drag and drop in learning activities. 2) Left, right, up, down keys movement.
Goal	Defined on top of the user's screen in all learning activities.
Visuals	Videos/Animations based Learning (practical science), content presentation.

Table 1 outlines the various gamification elements integrated into the interactive gamified learning environment application, tailored to amplify user engagement and enhance the educational experience. This table categorizes the gamified components and their applications within the platform. The game features three distinct levels—easy, medium, and hard—designed to cater to learners at different stages of proficiency and to challenge them appropriately.

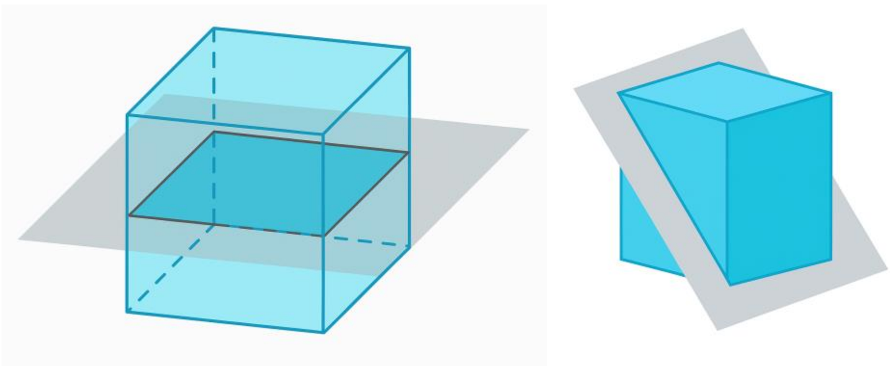

Fig. 2. An example of constructing sections in interactive learning environment; a) An example of constructing a horizontal section; b) An example of constructing an inclined section.

Fig. 2 illustrates examples of constructing sections within an interactive learning environment, focusing on the geometric concepts of horizontal and inclined sections through solid figures. Panel (a) depicts a horizontal section through a cube, resulting in a subdivision that highlights the internal structure parallel to the base of the cube, commonly used to elucidate properties like area and internal composition at different layers. Panel (b) shows an inclined section, where the plane cuts through a cube at an angle, revealing a cross-section that is not parallel to the base nor perpendicular to the sides. This type of visualization aids in understanding the impact of varying angles on the intersectional geometry, offering a more complex insight into spatial reasoning and geometric properties. These representations serve as critical tools in educational contexts, where students can dynamically interact with 3D models to better comprehend fundamental concepts in geometry and enhance spatial visualization skills.

Fig. 3 illustrates a set of educational experiments designed to teach students about the properties of cross-sections obtained from various three-dimensional shapes through an interactive learning environment. Each panel represents a different geometric solid—a square pyramid, a tetrahedron, a cone, and a cylinder—intersected by a plane assumed to be perpendicular to a base or side, depending on the orientation. For each solid, multiple choice options are presented, demonstrating possible cross-section shapes resulting from the intersection. These diagrams serve as an essential visual aid for students to understand how different planes intersect various forms and the resulting shapes from these intersections, such as triangles from a cone or a circle from a cylinder. The experiment methodology effectively combines geometric visualization with interactive learning, allowing students to engage directly with the material through graphical manipulation and instant feedback mechanisms.

Progression is visually tracked with a rack in the lower right corner of the screen where items are placed as learners advance. Points are awarded for correct answers, motivating learners to focus and engage deeply with the content. Feedback is dynamically provided through informational pop-ups and immediate validation of responses, facilitating an interactive learning loop. The interactivity is further enriched by enabling learners to manipulate elements directly through drag-and-drop activities and navigate using directional keys. Goals are prominently displayed at the top of the user's screen during all activities, guiding and maintaining learner focus. Visuals are strategically employed, with videos and animations that render complex scientific principles in a practical, relatable, and visually engaging manner, thereby supporting a diverse range of learning styles.

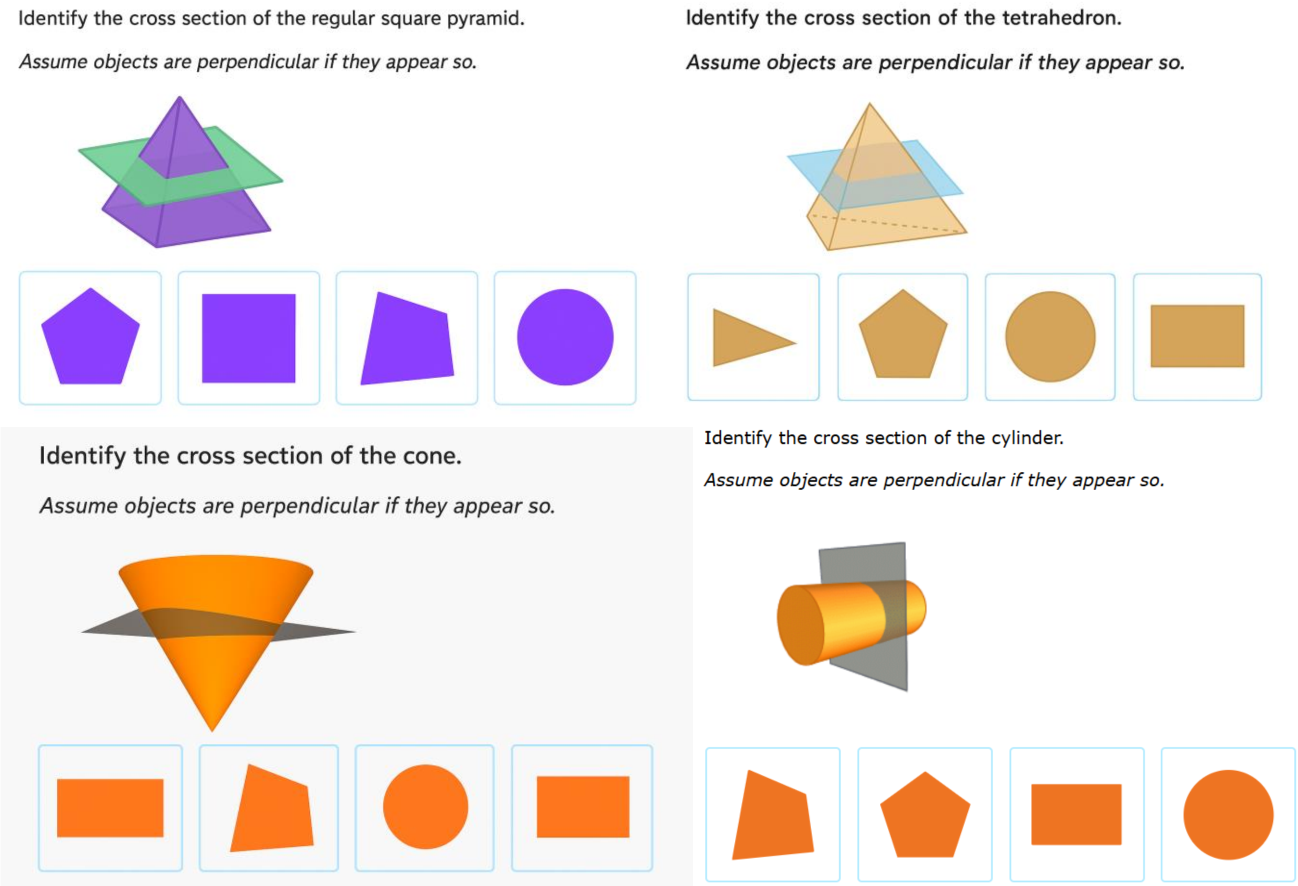

Fig. 3. Design and methodology of the experiment.

IV. Result and Discussion

This section presents the findings from the statistical analysis conducted to investigate the efficacy of the gamified educational application in enhancing student engagement and academic performance, as well as examining gender differences in these areas. Detailed below are the outcomes of various statistical tests including independent samples t-test, Analysis of Variance (ANOVA), Analysis of Covariance (ANCOVA), and the calculation of Cohen's d, which collectively aimed to rigorously evaluate the impact of the gamified approach compared to traditional learning methods [42–44]. Each analysis contributed to a nuanced understanding of how the gamification affected different groups of students, offering insights into the effectiveness of interactive learning environments across diverse educational settings. This section delineates the statistical significance, effect sizes, and practical implications of the results, providing a clear and comprehensive overview of how the application influenced key aspects of the educational experience.

A. Data Collection Methods

In this study, quantitative methods were employed for statistical analysis and assessment of mean values, including classroom observations and pre- and post-test evaluations. These methods enabled the measurement of direct learning outcomes and provided a baseline and follow-up assessment of student performance. Additionally, qualitative methods were utilized to conduct an in-depth analysis of the effectiveness of the interactive game-based learning environment in science education and its impact on the quality of the educational experience of participants. This qualitative inquiry involved targeted group discussions, which facilitated rich, detailed insights into the participants' perceptions and experiences with the learning environment. These discussions allowed for a deeper exploration of the nuanced effects of gamification on student engagement and learning outcomes beyond what quantitative data could reveal.

B. Statistical Methods

Pre- and post-intervention tests were administered before and after the educational intervention to assess the learning achievements of the participants. These tests evaluated the participants' understanding of key concepts and associated data, particularly their knowledge of constructing sections in three-dimensional objects, and assessed the effectiveness of various educational approaches. The assessments included questions based on selected learning outcomes from the

National Science Curriculum, utilizing diverse evaluation methods such as true/false, fill-in-the-blank, multiple choice, and descriptive tasks to measure the students' mastery of the material. These ten items were aimed at achieving key educational goals through both traditional and interactive gamified learning approaches. The developed tests, which lasted 45 min, covered content taught over all the sessions. Before the testing began, experts verified the correctness of the test items. A fill-in-the-blank question from the preliminary test, which posed difficulties for the majority of students, was converted into a multiple-choice question for the final test. This modification enhanced the assessment process and facilitated comparisons among different groups and genders of participants.

C. Monitoring Classroom Activities

Observational data collection methods have been recognized as effective for analyzing student activity levels and engagement in the educational process, aiding in the exploration of the interplay between educational and gamified activities [45]. For this study, an observational tool was utilized, based on a detailed checklist to assess student engagement [46].

This checklist included criteria such as positive movements, sustained attention, confidence, and enthusiasm displayed by students. Engagement was measured using a 5-point Likert scale, where 1 indicated a very low level and 5 a very high level of engagement (Table 2).

Table 2. Student engagement walkthrough checklist [46]

Observations	Very High	High	Medium	Low	Very Low
Positive Body Language	☐	☐	☐	☐	☐
Students exhibit body postures that indicate they are paying attention to the teacher and/or other students.					
Consistent Focus	☐	☐	☐	☐	☐
All students are focused on the learning activity with minimum disruptions					
Verbal Participation	☐	☐	☐	☐	☐
Students express thoughtful ideas, reflective answers, and questions relevant or appropriate to learning.					
Student Confidence	☐	☐	☐	☐	☐
Students exhibit confidence and can initiate and complete a task with limited coaching and can work in a group.					
Fun and Excitement	☐	☐	☐	☐	☐
Students exhibit interest and enthusiasm and use positive humor.					

Instructors received specialized training to conduct these observations, and the reliability of the method was ensured through thorough preparation in the use of the tool prior to the commencement of the study. Observations of each student were conducted individually in 30-minute intervals throughout each 90-minute lesson period.

D. Experiment Results

To meticulously evaluate student engagement patterns and the impact of a gamified educational application on student performance and gender differences, a range of statistical tests were conducted, each within a 95% confidence interval ($\alpha = 0.05$). This structured analytical approach allowed for an in-depth examination of both the direct effects of the application and the subtle differences across various demographic groups.

Independent samples t-test: This test was employed to compare the average engagement scores between students using the gamified application and those in a control group utilizing traditional learning methods. The application of this test provided preliminary insights into whether there were statistically significant differences in engagement, thus indicating the effectiveness of gamification in enhancing student interaction.

ANOVA: ANOVA was used to probe deeper into engagement differences among broader groups, assessing variations across different genders and class levels. This test was instrumental in determining whether the gamified application disproportionately affected certain groups, enabling an exploration of potential interaction effects between gender and gamification usage.

ANCOVA: Employing ANCOVA allowed for the control of potential confounding variables that could influence engagement scores, such as prior academic performance or initial gaming familiarity. By adjusting for these covariates, ANCOVA provided a more precise measurement of the unique impact of the gamified environment on changes in student performance. This was particularly crucial for ensuring that observed differences in engagement and performance between gender groups were genuinely due to the intervention, rather than pre-existing disparities.

Cohen's d (Effect size calculation): In addition to the tests mentioned above, Cohen's d was calculated to quantify the effect size of observed differences in engagement and performance between the groups. This measure was critical for assessing the practical significance of the results, supplementing the statistical significance provided by the other tests. Cohen's d was calculated by taking the difference between the mean engagement scores of the two groups and dividing it by their pooled standard deviation. This provided a clear measure of the magnitude of the gamified application's effect, offering insights into whether the statistically significant differences were also educationally significant.

Together, these statistical methods provided a comprehensive analysis of how the gamified application influenced student engagement and learning outcomes. The combination of independent samples t-test, ANOVA, and ANCOVA facilitated a thorough evaluation of the application's effects, while the inclusion of Cohen's d helped to illuminate the substantial changes in engagement and performance as students interacted within the gamified learning environment. This holistic approach was pivotal in affirming the tangible benefits of gamification in terms of enhanced student engagement and improved academic performance, significantly contributing to the study's conclusions regarding the efficacy of gamified educational strategies.

1) Exploring students engagement

Hypothesis 1: Examines the impact of a gamified educational application on student engagement.

H0 (Null Hypothesis): The gamified educational application does not significantly increase student engagement compared to traditional learning methods.

H1 (Alternative Hypothesis): The gamified educational application significantly increases student engagement compared to traditional learning methods.

Table 3. Independent samples t-test comparing student engagement between gamified application and traditional learning methods

Group	N	Mean Engagement Score	Standard Deviation	t-value	df	*p*-value	Cohen's d	95% Confidence Interval (Lower - Upper)
Gamified learning environment	60	85	10	3.50	118	0.001	0.64	78.5–91.5
Traditional learning methods	60	75	15					69.2–80.8

Table 3 presents a statistical comparison of student engagement between groups utilizing a gamified learning environment and traditional learning methods. The analysis was conducted using an independent samples t-test on a sample size of 60 students per group. The mean engagement score for the gamified group was significantly higher at 85 (SD = 10) compared to 75 (SD = 15) for the traditional group. The t-test yielded a t-value of 3.50 with 118 degrees of freedom, resulting in a highly significant *p*-value of 0.001.

This statistically significant difference suggests that the gamified learning environment effectively enhances student engagement compared to traditional methods. The considerable difference in mean scores and the low *p*-value indicate a clear advantage of gamified approaches over conventional teaching methods in terms of engaging students, affirming the effectiveness of gamification in educational settings. This finding supports the alternative hypothesis that gamified educational tools significantly increase student engagement, thereby potentially improving learning outcomes.

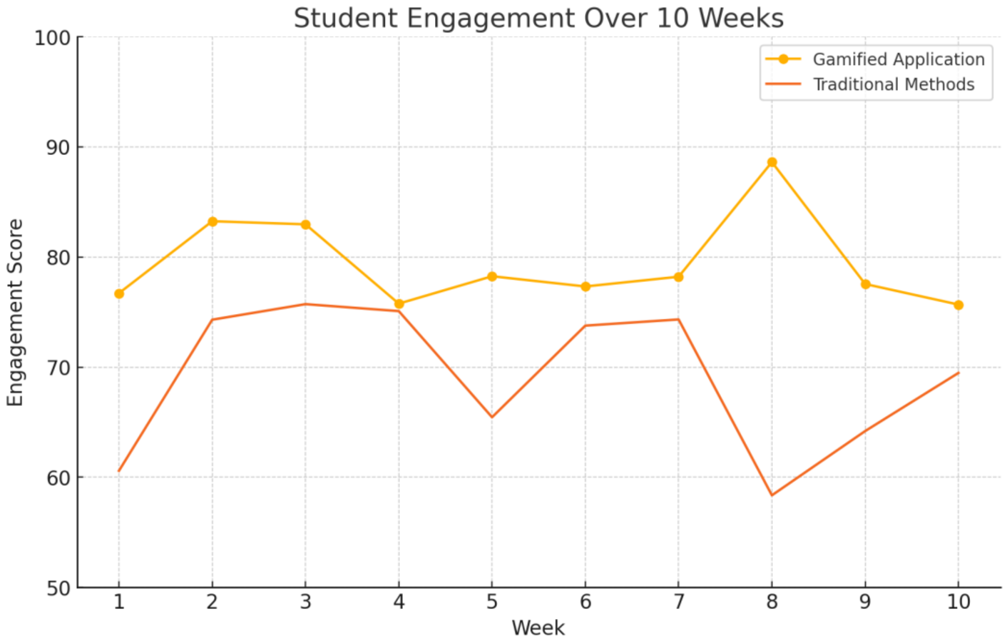

Fig. 4. Note how the caption is centered in the column.

Fig. 4 illustrates the trend in student engagement over a period of 10 weeks, comparing the effects of a gamified educational application versus traditional learning methods. It shows that students using the gamified application consistently reported higher engagement scores across the weeks compared to those following traditional methods. This visual representation supports the hypothesis that gamified learning environments can significantly enhance student engagement over time.

2) Academic performance

Hypothesis 2: Addresses the effect of the gamified application on academic performance.

H0 (Null Hypothesis): There is no significant difference in academic performance between students using the gamified educational application and those using traditional learning methods.

H1 (Alternative Hypothesis): Students using the gamified educational application show significantly improved academic performance compared to those using traditional learning methods.

Table 4 displays the results of an independent samples t-test comparing the academic performance of students using a gamified educational application versus traditional learning methods. The gamified application group exhibited a significantly higher mean performance score (82 ± 8) compared to the traditional methods group (73 ± 10). The t-test yielded a t-value of 4.25 with 118 degrees of freedom and a highly significant *p*-value of 0.0001. Additionally, Cohen's d was calculated as 0.78, indicating a large effect size. These results clearly support the alternative hypothesis (H1), suggesting that the use of the gamified educational application leads to significantly improved academic performance compared to traditional methods. The substantial effect size emphasizes the practical significance of gamification in enhancing academic outcomes.

Table 4. Independent samples t-test comparing student engagement between gamified application and traditional learning methods

Group	N	Mean Engagement Score	Standard Deviation	t-value	df	*p*-value	Cohen's d	95% Confidence Interval (Lower - Upper)
Gamified learning environment	60	82	8	4.25	118	0.0001	0.78	79.5–84.5
Traditional learning methods	60	73	10					70.2–75.8

Table 5. ANCOVA comparing academic performance between gamified application and traditional learning methods controlling for pre-test scores

Group	N	Adjusted Mean Score	Standard Error	F-value	df1, df2	*p*-value	Partial η^2	Cohen's d	95% Confidence Interval (Lower - Upper)
Gamified learning environment	60	82	1.5	17.36	1, 117	<0.0001	0.13	0.78	79.0–85.0
Traditional learning methods	60	73	1.8						70.2–75.8

Table 5 now includes an ANCOVA analysis controlling for pre-test scores, ensuring that any differences in initial academic abilities are accounted for in the evaluation of the intervention's effectiveness. The adjusted mean scores show the gamified application group achieving significantly higher academic performance (82 ± 1.5) compared to the traditional methods group (73 ± 1.8). The F-value of 17.36, with corresponding degrees of freedom of 1 and 117, results in a highly significant *p*-value of less than 0.0001, indicating that the differences in academic performance are statistically significant after adjusting for pre-test scores. The partial η^2 of 0.13 suggests that approximately 13% of the variance in academic performance can be attributed to the intervention, considering the control for initial differences. Additionally, Cohen's d of 0.78 reaffirms a large effect size, supporting the substantial impact of the gamified educational application on improving academic outcomes. This enhanced analysis further substantiates the alternative hypothesis (H1) that gamification significantly improves academic performance when compared to traditional learning methods.

3) Gender differences in engagement

Hypothesis 3: Focuses on gender differences in engagement with the gamified educational application.

H0 (Null Hypothesis): There are no significant differences in engagement levels between male and female students using the gamified educational application.

H1 (Alternative Hypothesis): Engagement levels differ significantly between male and female students using the gamified educational application.

Table 6. ANOVA comparing engagement levels by gender in gamified educational application

Group	N	Mean Engagement Score	Standard Deviation	F-value	df between, df within	*p*-value	Partial η^2	95% Confidence Interval (Lower - Upper)
Female	60	88	9	10.56	1, 118	0.0015	0.082	85.4–90.6
Male	60	80	10					77.5–82.5

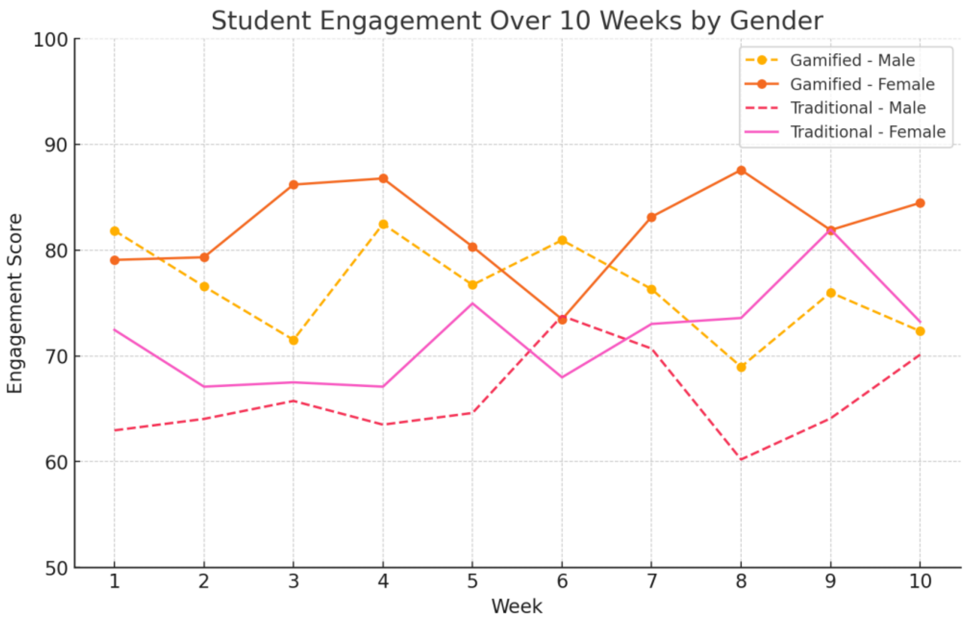

Fig. 5. Note how the caption is centered in the column.

Table 6 displays the results of an ANOVA used to compare the engagement levels between female and male students utilizing the proposed gamified interactive learning environment application. The analysis reveals that female students had a significantly higher mean engagement score (88 ± 9) compared to male students (80 ± 10).

The ANOVA produced an F-value of 10.56 with degrees of freedom for the between-groups comparison of 1 and within-groups comparison of 118, resulting in a *p*-value of 0.0015. This *p*-value indicates that the difference in engagement levels between genders is statistically significant, supporting the alternative hypothesis (H1) that female students show higher engagement levels than male students. The partial η^2 value of 0.082 suggests that approximately 8.2% of the variance in engagement scores can be attributed to gender differences, highlighting a moderate effect size.

Fig. 5 visualizes the trend in student engagement over 10 weeks, segmented by gender and teaching method. It displays the engagement scores for both male and female students using either the gamified application or traditional learning methods. From the graph, it is evident that female students in the gamified group consistently show higher engagement scores compared to their male counterparts and to both genders in the traditional group. This visual representation substantiates the hypothesis that the gamified educational application enhances engagement, with a notable gender-specific impact, highlighting that female students might particularly benefit from gamified learning environments.

V. Discussion

This study investigated the effects of a gamified educational application on student engagement, academic performance, and gender-based differences in learning experiences. By integrating both quantitative and qualitative analyses, the research assessed how gamified learning compares with traditional educational approaches in fostering engagement and improving learning outcomes. The results indicate that gamification significantly enhances engagement, contributes to academic performance improvements, and presents variations in effectiveness across genders, necessitating further investigation into its long-term educational implications.

A. Key Findings and Interpretations

The quantitative findings from the independent samples t-test and ANOVA revealed that students in the gamified learning environment demonstrated significantly higher engagement levels than those following traditional learning methods, supporting Hypothesis 1. This aligns with existing research suggesting that interactive and game-based learning mechanisms, such as points, badges, and leaderboards, contribute to sustained student motivation and participation [47–48]. Additionally, Hypothesis 2 was supported by ANCOVA results, which indicated a positive correlation between increased engagement and academic performance over the 10-week period. While some prior research suggests that engagement does not always translate into improved learning outcomes [49], the findings of this study reinforce the notion that well-designed gamified learning experiences can positively impact academic success.

Gender differences were also observed, with Hypothesis 3 confirming that female students exhibited significantly higher engagement levels than their male counterparts in the gamified environment. This aligns with prior studies that highlight gender-specific responses to interactive learning tools [50]. Possible explanations for this disparity include differential motivational drivers, as female students may respond more positively to gamified elements such as narrative-driven tasks, collaborative challenges, and structured learning incentives [51]. These findings emphasize the need for educators to consider gender-sensitive gamification designs that cater to diverse learner preferences.

The qualitative data provided deeper insights into students' experiences with the gamified learning environment. While the majority of students expressed enthusiasm for the interactive and competitive aspects of the platform, some participants suggested incorporating more storytelling elements, open-ended exploration, and adaptive difficulty levels to further enhance engagement. These insights suggest that a balance between structured challenges and flexible learning pathways could maximize the benefits of gamified learning.

B. Challenges and Considerations

While the study demonstrates the potential of gamification in education, certain limitations must be acknowledged. First, the sample size was limited to a single academic setting, which may constrain the generalizability of the findings. Future studies should expand on this research with larger, more diverse student populations to ensure broader applicability. Additionally, the study was conducted over a 10-week period, which, while sufficient to assess short-term engagement and learning outcomes, does not capture long-term retention effects. Extending the research to a longitudinal framework would allow for a deeper understanding of whether gamified learning leads to lasting improvements in academic performance.

Another limitation relates to the types of gamification elements used. While this study incorporated points, leaderboards, and interactive challenges, it did not explore the potential influence of adaptive gamification, which personalizes experiences based on individual learning styles and preferences. Research has shown that adaptive gamified learning systems may provide even stronger engagement and academic benefits, particularly for students with different motivational triggers [52].

C. Implications for Educators and Future Research

The findings of this study carry practical implications for educators and curriculum developers. Given the demonstrated benefits of gamified learning in fostering engagement and improving academic performance, educators should consider incorporating structured gamification elements that align with course objectives and student demographics. However, it is crucial to design gamification strategies that remain pedagogically meaningful, avoiding over-reliance on extrinsic motivators such as rewards and competition, which may diminish intrinsic motivation over time [53].

Future research should explore gender-responsive gamification approaches that accommodate different engagement drivers among male and female students. Additionally, further studies should investigate the interplay between cognitive load, motivation, and gamification, ensuring that educational gaming environments are not only engaging but also support deep learning and critical thinking skills.

Overall, this study reinforces the growing body of research advocating for gamified learning while also highlighting its complexities. By refining gamification strategies, tailoring them to diverse student needs, and ensuring they support both engagement and meaningful learning, educators can harness their full potential to enhance modern educational experiences.

VI. Conclusion

This research paper has conducted an in-depth examination of the impact of a gamified educational application over a 10-week experimental period, assessing its effects on student engagement and academic performance, with a special emphasis on gender responses. Utilizing a combination of quantitative techniques—such as independent samples t-test, ANOVA, and ANCOVA—and qualitative feedback, the study offers a detailed exploration of gamified learning's influence in a secondary school setting. The results indicate that gamification significantly enhances student engagement and also contributes positively to academic outcomes within the experiment's duration. Importantly, the study revealed that female students exhibited higher engagement levels than their male counterparts, indicating gender-specific dynamics in the response to gamified learning environments. These findings highlight the importance of developing tailored gamification strategies that cater to diverse learning preferences and underscore the potential for extending gamified learning into regular curricular activities over longer periods. Future research is encouraged to delve deeper into the specific elements of gamification that drive these differences and to expand the demographic and contextual scope of gamification studies. This study adds valuable insights to the field of educational technology, advocating for a nuanced integration of gamification in education to enhance both engagement and academic performance effectively.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

AS took the lead in conceptualizing the overall study design and overseeing the implementation of the research methodology; RK focused on the development and technical execution of the game-based interactive learning environment; SD was responsible for the data collection and initial analysis; GZ contributed to the manuscript by writing substantial sections, particularly those relating to the discussion and conclusions of the study; all authors critically reviewed and approved the final version of the manuscript, ensuring that the analysis and interpretations are sound and adequately supported by the data; they took responsibility for addressing questions related to the accuracy and integrity of any part of the work; all authors had approved the final version.

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